Published in final edited form as:

J Subst Abuse Treat. 2009 October ; 37(3): 292–297. doi:10.1016/j.jsat.2009.03.004.

Drug Abstinence and Cognitive Control in Methamphetamine Dependent Individuals

R Salo^{1,2}, TE Nordahl^{1,2}, GP Galloway³, CD Moore^{2,4}, C Waters³, and MH Leamon²

¹UC Davis Imaging Research Center, Sacramento, CA

²Dept. of Psychiatry and Behavioral Sciences, University of California Davis Medical Center, Sacramento, CA

³St. Luke's Hospital, San Francisco, CA

⁴Kaiser Chemical Dependence Recovery Program, Sacramento, CA

Abstract

Chronic methamphetamine (MA) abuse is associated with disruption of frontostriatal function as well as deficits in cognitive control. In order to examine the relationship between drug use patterns and cognitive deficits we pooled previously published behavioral data with new data collected using the Stroop Attention Test. Subject groups comprised 38 MA abusers who recently initiated abstinence [36.1 ± 8.8 yrs of age], 27 MA abusers who had initiated abstinence > one year prior to study [38.7 ± 7.7 yrs of age] and 33 non-substance abusing controls [33.9 ± 8.5 yrs of age]. The recently abstinent MA abusers exhibited greater Stroop reaction time (RT) interference compared to both the control group [$p = .001$] and the Long-term abstinent MA abusers [$p = .01$]. No difference was seen between long-term abstinent MA abusers and controls [$p = .87$]. Stroop RT interference correlated positively with both duration of drug use [$p = .003$] and drug abstinence [$p = .05$]. The data in the current study provide evidence that cognitive function may improve with protracted drug abstinence.

Keywords

Methamphetamine; drug abstinence; cognition; attention; Stroop

1. Introduction

In the past decade the use of the stimulant methamphetamine (MA) has increased in the general population with more than 35 million people estimated to use amphetamine-like drugs throughout the world (SAMSHA, 2004, 2006). The statistics on the growing pandemic of MA abuse are overwhelming and include the following: 1) admissions to substance abuse treatment programs with MA as the primary substance increased 182% from 1994 to 2004, with 44 out of 45 states reporting increases (DHHS, 2006); 2) emergency room admissions related to MA use have doubled during the period of 1994 to 2002 (Justice, 2005); and 3) several acts of national legislation, such as the Comprehensive Methamphetamine Control Act of 1996 and

Address correspondence to: Ruth Salo, UC Davis Imaging Research Center, 4701 X Street, Phone: 916-734-7909, Fax: 916-734-8520, e-mail: resalo@ucdavis.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

the Methamphetamine and Club Drug Anti-Proliferation Act of 2000, have focused specifically on the growing problem of MA abuse throughout the United States (DHHS, 2004; Gibson et al., 2002; Justice, 2005). Compounding the problem is evidence that psychostimulants, such as MA, are neurotoxic to dopaminergic frontostriatal brain regions with corresponding deficits in selective attention and cognitive control (Nordahl et al., 2003; Quinton and Yamamoto, 2006; Simon et al., 2000).

Cognitive impairments exhibited by MA dependent individuals may be a result of neurotoxic effects to multiple neurotransmitter systems distributed throughout the cortex (Nordahl et al., 2003; Quinton and Yamamoto, 2006). Damage following MA abuse to frontostriatal brain regions such as the striatum, prefrontal cortex, anterior cingulate cortex and amygdala may contribute to the wide range of cognitive deficits observed in MA dependent human subjects. Cognitive deficits have been observed in MA dependent individuals with increased performance deficits appearing on tasks that require the suppression of task irrelevant information (Kalechstein et al., 2003; Monterosso et al., 2005; Salo et al., 2008; Salo et al., 2007), decision-making (Paulus et al., 2003; Paulus et al., 2005), and working memory (Chang et al., 2002; McKetin and Mattick, 1997, 1998). Although numerous studies have documented cognitive deficits in MA abusers, few have examined the role of abstinence on cognitive processes (Simon et al., 2004; Volkow et al., 2001). One longitudinal study followed three groups of MA abusers for six months and reported that the MA abusers who remained abstinent performed worse on a subset of the neuropsychological tasks compared to those abusers who used continuously or who relapsed (Simon et al., 2004). Another imaging study that re-tested five MA abusers at a 12-17 month period of abstinence showed significant improvement on a subset of cognitive tasks that assessed motor and memory function (Volkow et al., 2001).

1.1. Study Rationale

The goal of the present study was to examine the relationship between drug usage status (i.e., years of use and time since last use) and performance on the single-trial version of the Stroop attention task. The Stroop task is a widely validated measure of response inhibition and cognitive control in clinical populations, (Carter et al., 1992; Ochsner et al., 2001; Swick and Jovanovic, 2002) and is therefore a powerful tool to assess cognitive control and attention in MA abusing subjects. Cognitive control is defined as the ability to flexibly adapt behavior to current demands, by promoting task-relevant information and behaviors over temporally-extended periods in the face of attentional interference (Botvinick et al., 2001). In the context of addiction, cognitive control is interpreted as the inhibition of a prepotent response (e.g., compulsive drug use) in order to carry out behaviors associated with long-term rewards and positive outcomes (e.g., abstaining from drug use). The ability to engage cognitive control and overcome the impulse to engage in drug-seeking behavior may be a key component of remaining abstinent. If the two processes are related (i.e., refraining from drug seeking and cognitive control) then one might predict that performance on a task that measures cognitive control (i.e., Stroop task) and length of drug abstinence might be linked.

In order to examine the relation between MA abstinence and cognitive control, we pooled new, unpublished behavioral data from 21 MA dependent subjects with data from 44 subjects previously reported in two published studies (Salo et al., 2007; Salo et al., 2002). All data reported in the current study were generated using the same version of the single-trial Stroop attention task. Although different versions of the Stroop task are available (MacLeod, 1991; Salo et al., 2001), the computerized single-trial version has advantages over the paper version in that: 1) more precise reaction times (RTs) can be recorded in milliseconds; 2) RTs are not summed across a large stimulus set thus controlling for outliers; 3) errors can be recorded for individual stimuli; and 4) single word stimuli can be presented without the presence of distractors that may impact attentional performance in clinical populations (Boucarter et al.,

1999; Salo et al., 2001). Given the powerful neurotoxic profile of MA we predicted that longer duration of MA use would correlate with greater deficits on the Stroop attention task as measured by increased RT Stroop interference. In addition, given the evidence from the neuroimaging literature on the normalization of brain function over periods of protracted MA abstinence (Nordahl et al., 2005; Volkow et al., 2001), we also predicted an inverse correlation between RT Stroop interference and time drug abstinent. Specifically we predicted that those MA dependent individuals with longer periods of MA abstinence would exhibit the lowest RT Stroop interference scores.

2. Materials and methods

2.1. Subjects

Sixty-five MA dependent subjects (28 males and 37 females) were recruited through outpatient substance abuse treatment centers. 38 MA abusers had recently initiated abstinence (three weeks to six months) and 27 MA abusers had initiated abstinence > one year prior to study. The recent and distant abstinent MA abusers did not differ from each other in age [$F(1,63) = 1.46$; $p = .23$], years MA use [$F < 1$], education [$F < 1$], or scores on a measure of premorbid IQ as determined by the National Adult Reading Test (NART) [$F < 1$]. All MA abusing subjects had been diagnosed with MA Dependence as determined by the Structured Clinical Interview for DSM Disorders (SCID) and had been drug abstinent a minimum of 3 weeks. (First et al., 1995). Random urine screens were performed at the referring sites to verify drug abstinence and none of the screens yielded positive results.

Exclusionary criteria included the following: 1) history of significant head trauma or neurological injury; 2) co-occurring non-substance related Axis I disorder; and 3) substance dependence other than MA (except nicotine) within the past year and no alcohol abuse in five years. All subjects reported normal color vision and normal or corrected to normal visual acuity. The 65 MA dependent subjects had been drug abstinent for a minimum of three weeks and a maximum of ten years. Median length of MA abuse was 12 years and median duration of MA abstinence was four months.

33 non-substance using controls (21 males and 12 females) were recruited from the surrounding community. Exclusionary criteria determined from the SCID included the following: 1) history of significant head trauma or neurological injury; 2) presence of an Axis I disorder; and 3) history of drug or alcohol abuse within the last year. Although the combined MA group and controls did not differ significantly in age [$F < 1$], the Long-term Abstinent group was slightly older than the Controls [$p = .04$]. There was a significant group difference in education levels [$F(2,95) = 10.4$; $p < .001$], with the controls having more education [mean = 14.6 years; $SD = 2.2$] than both the Recent Abstinent Group [mean = 12.7 years; $SD = 1.8$] and the Long-term Abstinent Group [mean = 12.9; $SD = 1.5$]. Demographic characteristics are reported in Table 1. All subjects signed informed consent and received a modest stipend for their participation in the study.

2.2. Stimuli

Stroop Attention Task—Four colors were employed: red, green, blue, and yellow. The incongruent stimuli were created by printing each of the four color names in one of the three other ink-colors. The congruent stimuli were created by printing each of the four color names in its own color. The neutral stimuli consisted of strings of XXXXs printed in one of the four ink colors. Each letter within the stimulus words and neutrals was printed in upper case and subtended 1 degree vertically. The width of each word and neutral displayed varied as a function of the number of letters presented (range 3 - 6 letters; 2.4 - 5.4 visual degrees). Each trial began with a fixation cross presented for 500 milliseconds (msec) followed by the stimulus

at the center of the screen. The onset of the subject's voice triggered the voice-operated relay switch (recorded by the computer to the nearest msec) and terminated the stimulus display on the screen. The experimenter then typed in the first letter to record the subject's response accuracy, which also initiated the subsequent trial. The response stimulus interval employed was 494 msec. There were two blocks of trials; each one composed of 162 randomly presented stimuli: 58 neutrals, 54 congruent, and 50 incongruent. One practice block was administered, but was not included in the analysis.

2.3. Procedure

Stimuli were presented on a 14" VGA color monitor. An IBM compatible computer controlled stimuli presentation and data collection. Voice responses were recorded via a voice-operated relay interfaced to the microcomputer. Subjects were instructed to say aloud as rapidly as possible the color of ink that the words were printed in while ignoring the word itself. Subjects were given instructions designed to avoid a speed-accuracy trade-off in that they were told to respond as quickly as they could without making too many mistakes.

2.4. Data Analysis

Median RTs for correct responses for every condition were computed for each subject. Medians were used instead of means to reduce the influence of outlier responses, which can exaggerate group differences (Ratcliff, 1993). Analysis of variance procedures (ANOVA) for repeated measures were used to analyze the data in a 3×2 mixed ANOVA with group (Recent Abstinent vs Long-term Abstinent vs Controls) as between subjects factor and wordtype (incongruent vs neutral) as within subjects variables. Planned comparisons of within-trial effects for interference (median incongruent RT minus median neutral RT) were performed. Given the lack of group differences in facilitation effects in previous studies (Salo et al., 2007; Salo et al., 2002), these effects were not analyzed.

3. Results

3.1. Reaction Time Analysis

Analyses revealed main effects of group [$F(2, 95) = 4.22, p = .02$] and Stroop wordtype [$F(2, 190) = 473.88, p < .0001$] as well as a significant interaction between group and wordtype [$F(4, 190) = 5.63, p = .0001$]. Planned analyses revealed that interference effects were greater in the Recent Abstinent MA abusers (186 msec) compared to both the controls (132 msec) [$p = .002$] and the Long-term Abstinent MA abusers (138 msec) [$p = .001$]. RT interference effects did not differ significantly between the Long-term Abstinent MA abusers and the controls [$p = .87$]. Analyses of covariance (ANCOVA) controlling for differences in education and NART scores were also performed. The group differences in interference endured when both education and NART were employed as covariates [$p < .05$].

3.2. Error Analyses

Although error trials were not included in the RT analyses, further analyses examined the effect of error responses on within and between-trial effects. Analyses revealed that all three groups made significantly more errors in the incongruent condition (13%) than in the neutral condition (2%). The error rates did not differ between the three groups [$F < 1$]. Analyses revealed no evidence of a speed-accuracy trade-off for either subject group. In fact there was a positive correlation between RTs and errors [MA abusers: $r = .161, p = .20$; Controls: $r = .40, p = .02$]. Subjects with faster RTs made fewer conflict errors than those with longer RTs.

3.3. Correlations between Drug Use and Stroop Indices

Due to the non-linearity of the drug use data, square root transforms were performed on the drug use data prior to running Pearson Product correlations. Analyses revealed that longer RTs in the Stroop task (i.e., greater interference) correlated significantly with greater years of MA use [$r = .362$; $p = .003$]. Correlations between months abstinent and Stroop interference were trend significant [$r = .245$, $p = .047$] with longer periods of drug abstinence correlating with a reduction in Stroop interference. A multiple regression analysis with Stroop Interference as a dependent variable and years MA use and months MA abstinence as predictors revealed that the years MA use [$t = 3.16$; $p = .002$], contributed to Stroop interference over and above the contribution of months MA abstinent [$t = -2.13$; $p = .04$].

4. Discussion

The data show that the MA abusers in early stages of abstinence (3 weeks - 6 months) exhibited greater deficits in response inhibition and cognitive control compared to both the control group and the MA abusers who had initiated abstinence > one year prior to study. Of interest is the finding that RT interference effects did not differ significantly between the Long-term Abstinent MA abusers and the controls. This finding suggests that protracted drug abstinence may contribute to improvements in function on tasks that measure behavioral regulation and top-down control. This finding is accompanied by a modest inverse correlation between duration of abstinence and Stroop interference scores (i.e., greater months of drug abstinence linked to lower Stroop interference). The analyses also revealed a deleterious effect of the length of MA use on cognitive function with increased years of MA use contributing to increased RT Stroop interference. Importantly, not only does greater duration of MA use correlate with worse attentional performance, but a pattern of possible improvement in attentional performance associated with longer periods of drug abstinence emerges. This is an important finding with clinical applications as it suggests a behavioral correlate of neuronal recovery reported in neuroimaging studies of MA abusers (Nordahl et al., 2005; Volkow et al., 2001).

The findings in the current study appear to differ from those published by Simon et al. (Simon et al., 2004), who reported that currently using MA abusers performed better on a subset of neuropsychological tests compared to currently abstinent and relapsing MA abusers. However, in this study, the period of abstinence did not extend beyond six months, which is the cutoff for early abstinence in this study. Given this difference in time points, the findings in the two studies are actually consistent. The results from both studies suggest that at six months of MA abstinence abusers display pronounced evidence of cognitive impairment. Another reason that the findings by Simon et al. may differ from those in the current study is that the MA abusers in the current study appear to have a more extensive history of MA abuse. As the Simon et al. study did not address the correlation between duration of MA use and cognitive performance; we cannot rule this potential contributing factor out.

4.1. Limitations

A major limitation of this study is the cross-sectional design, which does not allow the establishment of a cognitive baseline in the individual subjects. To partially address this shortcoming, the Long-term Abstinent MA abusers and the Recent Abstinent MA abusers were matched on years of education, years of MA use, and age of onset of first MA use, as well as measures of premorbid IQ. Despite the lack of differences between the groups, further longitudinal studies are needed to extend and confirm the findings in the present study. Another possibility is that there may be other unknown factors that separate the Long-term Abstinent from the Recent Abstinent abusers. Perhaps individuals with less Stroop interference initially are more likely to go on to achieve longer durations of abstinence. Theoretically, some of these

folks would be in the Recent Abstinent sample, but the impact would be diluted by others. Another limitation of the current study is the lack of objective verification of sustained drug status in the Long-term abstinent sample and the controls via hair testing or ongoing urine screens. Despite this limitation, the findings strongly suggest that individuals who refrain from regular MA use show improvements in cognitive control and behavioral regulation. It is also possible that history of drug abuse other than MA, a common comorbidity of such individuals, could have contributed to the patterns of cognitive recovery. To minimize such effects, we studied subjects whose primary drug of choice was MA with no dependence on other drugs (except nicotine) and whose alcohol abuse was greater than five years prior to time of study.

5. Conclusion

The findings within the present study suggest that adaptive changes, as evidenced by improved attentional performance, may occur across periods of extended drug abstinence. These behavioral findings are consistent with imaging studies in MA abusers which suggest partial normalization of brain function (Nordahl et al., 2005; Volkow et al., 2001). More research is needed utilizing a longitudinal design to elucidate the mechanisms underlying these adaptive changes. The understanding of how the human brain may recover or partially recover as a function of extended drug abstinence has important implications both for the neurobiology of addiction as well as substance abuse treatment. If cognitive improvements occur across extended periods of abstinence; this finding would be clinically salient. These cognitive improvements can then be applied in substance abuse treatment programs and utilized as predictors of treatment outcome in vulnerable difficult to treat populations (Streeter et al., 2008).

Acknowledgments

This research was supported by a grant DA16329 to RES, DA14359 to TEN and DA10641 to GPG.

References

- Botvinick MM, Braver TS, Barch DM, Carter CS, Cohen JD. Conflict monitoring and cognitive control. *Psychological review* 2001;108:624–652. [PubMed: 11488380]
- Boucatt M, Mobarek N, Cuervo C, Danion JM. What is the nature of increased Stroop interference in schizophrenia? *Acta psychologica* 1999;101:3–25. [PubMed: 10100453]
- Carter CS, Robertson LC, Nordahl TE. Abnormal processing of irrelevant information in chronic schizophrenia: selective enhancement of Stroop facilitation. *Psychiatry research* 1992;41:137–146. [PubMed: 1574540]
- Chang L, Ernst T, Speck O, Patel H, DeSilva M, Leonido-Yee M, Miller EN. Perfusion MRI and computerized cognitive test abnormalities in abstinent methamphetamine users. *Psychiatry research* 2002;114:65–79. [PubMed: 12036507]
- DHHS. Health, N.I.O. Epidemiologic Trends in Drug Abuse - Advance Report. Bethesda, MD: 2004.
- DHHS. SAMHSA. Treatment episode data set (TEDS: 1994-2004). National admissions to substance abuse treatment services. DHHS; 2006.
- First, MB.; Spitzer, L.; Gibbon, M.; Williams, JBW. Structured Clinical Interview for DSM-IV Axis I Disorders. Biometrics Research Department; New York, NY: 1995.
- Gibson DR, Leamon MH, Flynn N. Epidemiology and public health Consequences of methamphetamine use in California's Central Valley. *Journal of psychoactive drugs* 2002;34:313–319. [PubMed: 12422943]
- Justice U.S.D.o. Center., N.D.I. National Drug Threat Assessment: Summary Report. Washington, DC: 2005.

- Kalechstein AD, Newton TF, Green M. Methamphetamine dependence is associated with neurocognitive impairment in the initial phases of abstinence. *The Journal of neuropsychiatry and clinical neurosciences* 2003;15:215–220. [PubMed: 12724464]
- MacLeod CM. Half a century of research on the Stroop effect: an integrative review. *Psychological bulletin* 1991;109:163–203. [PubMed: 2034749]
- McKetin R, Mattick RP. Attention and memory in illicit amphetamine users. *Drug and alcohol dependence* 1997;48:235–242. [PubMed: 9449023]
- McKetin R, Mattick RP. Attention and memory in illicit amphetamine users: comparison with non-drug-using controls. *Drug and alcohol dependence* 1998;50:181–184. [PubMed: 9649970]
- Monterosso JR, Aron AR, Cordova X, Xu J, London ED. Deficits in response inhibition associated with chronic methamphetamine abuse. *Drug and alcohol dependence* 2005;79:273–277. [PubMed: 15967595]
- Nordahl TE, Salo R, Leamon M. Neuropsychological effects of chronic methamphetamine use on neurotransmitters and cognition: a review. *The Journal of neuropsychiatry and clinical neurosciences* 2003;15:317–325. [PubMed: 12928507]
- Nordahl TE, Salo R, Natsuaki Y, Galloway GP, Waters C, Moore CD, Kile S, Buonocore MH. Methamphetamine users in sustained abstinence: a proton magnetic resonance spectroscopy study. *Archives of general psychiatry* 2005;62:444–452. [PubMed: 15809412]
- Ochsner KN, Kosslyn SM, Cosgrove GR, Cassem EH, Price BH, Nierenberg AA, Rauch SL. Deficits in visual cognition and attention following bilateral anterior cingulotomy. *Neuropsychologia* 2001;39:219–230. [PubMed: 11163601]
- Paulus MP, Hozack N, Frank L, Brown GG, Schuckit MA. Decision making by methamphetamine-dependent subjects is associated with error-rate-independent decrease in prefrontal and parietal activation. *Biological psychiatry* 2003;53:65–74. [PubMed: 12513946]
- Paulus MP, Tapert SF, Schuckit MA. Neural activation patterns of methamphetamine-dependent subjects during decision making predict relapse. *Archives of general psychiatry* 2005;62:761–768. [PubMed: 15997017]
- Quinton MS, Yamamoto BK. Causes and consequences of methamphetamine and MDMA toxicity. *The AAPS journal* 2006;8:E337–347. [PubMed: 16796384]
- Ratcliff R. Methods for Dealing With Reaction Time Outliers. *Psychological bulletin* 1993;114:510–532. [PubMed: 8272468]
- Salo R, Henik A, Robertson LC. Interpreting Stroop interference: an analysis of differences between task versions. *Neuropsychology* 2001;15:462–471. [PubMed: 11761035]
- Salo R, Leamon MH, Natsuaki Y, Moore C, Waters C, Nordahl TE. Findings of preserved implicit attention in methamphetamine dependent subjects. *Progress in neuropsychopharmacology & biological psychiatry* 2008;32:217–223.
- Salo R, Nordahl TE, Natsuaki Y, Leamon MH, Galloway GP, Waters C, Moore CD, Buonocore MH. Attentional control and brain metabolite levels in methamphetamine abusers. *Biological psychiatry* 2007;61:1272–1280. [PubMed: 17097074]
- Salo R, Nordahl TE, Possin K, Leamon M, Gibson DR, Galloway GP, Flynn NM, Henik A, Pfefferbaum A, Sullivan EV. Preliminary evidence of reduced cognitive inhibition in methamphetamine-dependent individuals. *Psychiatry research* 2002;111:65–74. [PubMed: 12140121]
- SAMSHA. Administration, S.S.A.a.M.H.S. The DASIS report: primary methamphetamine/amphetamine treatment admissions: 1992–2002. Office of Applied Studies; 2004.
- SAMSHA. Studies, O.o.A. National Admissions to Substance Abuse Treatment Services, DASIS Series. Treatment Episode Data Set (TEDS): 1994–2004. DHHS; 2006.
- Simon SL, Dacey J, Glynn S, Rawson R, Ling W. The effect of relapse on cognition in abstinent methamphetamine abusers. *Journal of substance abuse treatment* 2004;27:59–66. [PubMed: 15223095]
- Simon SL, Domier C, Carnell J, Brethen P, Rawson R, Ling W. Cognitive impairment in individuals currently using methamphetamine. *The American journal on addictions / American Academy of Psychiatrists in Alcoholism and Addictions* 2000;9:222–231. [PubMed: 11000918]
- Streeter CC, Terhune DB, Whitfield TH, Gruber S, Sarid-Segal O, Silveri MM, Tzilos G, Afshar M, Rouse ED, Tian H, Renshaw PF, Ciraulo DA, Yurgelun-Todd DA. Performance on the Stroop

predicts treatment compliance in cocaine-dependent individuals. *Neuropsychopharmacology* 2008;33:827–836. [PubMed: 17568399]

Swick D, Jovanovic J. Anterior cingulate cortex and the Stroop task: neuropsychological evidence for topographic specificity. *Neuropsychologia* 2002;40:1240–1253. [PubMed: 11931927]

Volkow ND, Chang L, Wang GJ, Fowler JS, Franceschi D, Sedler M, Gatley SJ, Miller E, Hitzemann R, Ding YS, Logan J. Loss of dopamine transporters in methamphetamine abusers recovers with protracted abstinence. *J Neurosci* 2001;21:9414–9418. [PubMed: 11717374]

Table 1
Demographic Characteristics of Methamphetamine Abusers

	Control Subjects (n = 33)	Recent Abstinent (n = 38)	Long-term Abstinent (n = 27)
Age, y, mean (SD)	33.9 (1.5)	36.1 (1.4)	38.7 (1.5) [†]
Females	11	19	18
Subject's education, y, mean (SD)	15.1 (2.1)	12.7 (1.8) ^{††}	12.9 (1.5) ^{††}
NART	114.0 (7.3)	107.5 (5.1) ^{††}	107.1 (5.3) ^{††}
Right-handed	29	36	23

[†]Significantly different from control group at $p < .05$

^{††}Significantly different from control group at $p < .01$

Table 2

Substance use Characteristics of Methamphetamine (MA) Abusers

	Recent Abstinent (n = 38)	Long-term Abstinent (n = 27)
MA use		
Duration, y, mean (SD)	13.4 (7.5)	13.9 (6.7)
Mos Abstinent, mean (SD)	2.6 (1.3)	31.5 (6.1) ^{††}
Age of first use, y, mean (SD)	19.1 (5.2)	18.6 (7.3)
Tobacco smokers	24	22

^{††} Significantly different at $p < .01$

Table 3

Median millisecond Reaction Times (RTs) and % Accuracy for Within-trial Stroop conditions Across Groups

Controls	Reaction Time in msec (SD)	% Incongruent Errors
Incongruent	767 (95.3)	.13 (.09)
Neutral	635 (73.5)	.02 (.04)
Interference	132	
Recent Abstinent	-	
Incongruent	862 (136.3)	.14 (.14)
Neutral	676 (90.9)	.03 (.05)
Interference	186 ^{††}	
Long-term Abstinent	-	
Incongruent	791 (108.5)	.12 (.08)
Neutral	653 (62.7)	.02 (.02)
Interference	138	

^{††} Significantly different from Control Group and Long-term Abstinent MA abusers at $p < .01$